up while under the influence of strain, so as to maintain the pressure constant, all gave similar and invariable results, but the results varied with the materials used. All metals, however, could be made to produce identical results provided the division of the metal was small enough, and that the material used does not oxidise by contact with the air filtering through the mass. Thus platinum and mercury are very excellent and unvarying in their results, whilst lead soon becomes of such high resistance through oxidisation upon the surface, as to be of little or no use. A mass of bright round shot is peculiarly sensitive to sound whilst clean, but as the shot soon become coated with oxide this sensitiveness ceases. Carbon, again, from its surface being entirely free from oxidation, is excellent, but the best results I have been able to obtain at present have been from mercury in a finely divided state. I took a comparatively porous non-conductor, such as the willow charcoal used by artists for sketching, heating it gradually to a white heat and then suddenly plunging it in mercury. The vacua in the pores, caused by the sudden cooling, become filled with innumerable minute globules of mercury, thus, as it were, holding the mercury in a fine state of division. I have also tried carbon treated in a similar manner with and without platinum deposited upon it from the chloride of platinum. I have also found similar effects from the willow charcoal heated in an iron vessel to a white heat, and containing a free portion of tin, zinc, or other easily vaporised metal. Under such conditions the willow carbon will be found to be metallised, having the metal distributed throughout its pores in a fine state of division. Iron also seems to enter the pores if heated to a white heat without being chemically combined with the carbon as in graphite, and, indeed, some of the best results have been obtained from willow charcoal containing iron in a fine state of division.

"Pine charcoal treated in this manner (although a non-conductor as a simple charcoal) has high conductive powers, due to the iron; and from the minute division of the iron in the pores, is a most excellent material for the purpose."

The substances above referred to are in practice confined in a glass tube or box, and provided with wires to enable them to be easily inserted into a circuit. This is called a transmitter.

The resistance of the conductors employed is affected by sounds absolutely inaudible, and it is this quality which Prof. Hughes utilises in what he calls *par excellence* his *microphone*. This marvellous instrument, of which we shall hear so much in the future, consists of a lozenge-shaped piece of gas-carbon one inch long, $\frac{1}{4}$ inch wide at its centre, and $\frac{1}{8}$ of an inch thick; the lower pointed end pivots upon a similar block, the upper rounded end plays free in another carbon block; all these pieces of carbon are tempered in mercury, and carbon is used in preference to any other material, as its surface does not oxidise. Prof. Hughes, in his paper, states:—

"The best form and materials for this instrument, however, have not yet been fully experimented on. Still, in its present shape, it is capable of detecting very faint sounds made in its presence. If a pin, for instance, be laid upon or taken off a table, a distinct sound is emitted, or, if a fly be confined under a table-glass, we can hear the fly walking, with a peculiar tramp of its own. The beating of a pulse, the tick of a watch, the tramp of a fly, can thus be heard at least a hundred miles distant from the source of sound. In fact, when further developed by study, we may fairly look for it to do for us, with regard to faint sounds, what the microscope does with matter too small for human vision."

The construction of the tube-transmitter exhibited to the Royal Society will be seen from the annexed woodcut. It consists of an exterior glass tube, G, two inches long and $\frac{1}{4}$ inch in diameter; in it are four separate pieces of willow charcoal. A is made to press on B, C, D, E, and F, until the resistance offered to the current is about one-third that of the line on which it is to be employed.

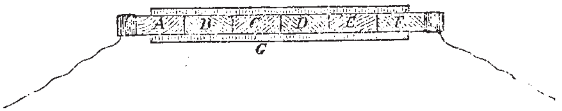

FIG. 2.

As Prof. Hughes properly remarks, it is as yet impossible to say what effect will flow from this wonderful discovery, a discovery which shows that it is possible to transmit clear and intelligent articulate speech, and to render the inaudible audible by the mere impact of sound waves upon matter along which an electric current is flowing.

It is not too early, however, to see that we have in the microphone a new method of attaching and quantifying molecular motions.

PHYSICAL SCIENCE FOR ARTISTS[1]

II.

THE examples I gave in my last paper were tested by a reference to the probable action of the aqueous vapour of our atmosphere in absorbing the various constituents of sunlight—the sun being the great source of light with which artists are specially concerned.

The reason that such a test was not applied long ago was because we are only just now beginning to understand why it is that the sun shines; why its light is white, and again why it is that this white light in passing through a great thickness of our atmosphere as it must do at sunrise and sunset—when the beams graze the surface of the earth instead of impinging upon it at a high angle—is in great measure absorbed or used up before it gets to the eye. The result of the condition to which I have just referred is familiar to all; at sunrise and sunset the sun is red and not white.

The light of the sun we know now is due to the quivering or vibration of the molecules of the matter of which the sun is composed. No molecular vibration no light; given molecular vibration, the more intense it is the more intense is the light produced. The absorption of the sunlight by our air in the manner I have stated is due to the molecules of our air already in vibration being set in still stronger vibration by the sunlight passing through them. Here again then we have molecules and vibrations. In short the vibration of molecules, so far as light is given out or reflected or quenched by them, sharply defines the physical region in which artists are chiefly interested.

In a work which recently appeared,[2] I have tried to show how the actions involved in sending a telegraphic message may help us to form a mental image of what goes on before the sensation of light is produced; we have a sending instrument, a medium, and a receiving instrument.

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[1] Continued from p. 31.

[2] "Studies in Spectrum Analysis."

The first, under all circumstances, is a molecule or series of molecules in vibration, and the quality of the light depends upon the vibration either inherent in the molecule or dependent upon the quality of the energy which sets it in vibration or controls the vibration.

The second is the ether, which does for light what our atmosphere does for sound. Competent to transmit vibrations of all lengths without loss of energy, it behaves with perfect fairness, so to speak, to light of all kinds.

The third, the receiving instrument, in our case is the eye of the artist above all things, but not to the exclusion of everything else, because every object which reflects light must receive it first, and sometimes important modifications are brought about in the act of reflection. To mention two instances :—white light from the sun falls on a leaf, but leaves appear green by the light which they reflect, and this transformation is the result of molecular work. The light of the moon is yellow in comparison with sunlight for the same reason, and the difference between sunlight and moonlight effects has its origin in the lunar molecules.

We call the light of the sun white, and much of the action of light may be studied by supposing this light to be a simple thing, by which I mean non-compound. A hole in a shutter through which the sun shines will convince us that light travels in straight lines. The idea of a modern novelist that light can travel spirally through a key-hole is not based on fact.

It may happen, too, if there be a brightly illuminated object outside the hole in the shutter, that another point not to be neglected will be illustrated. Because light does travel in straight lines the various rays coming from the different parts of an object and passing through a small aperture will build up an inverted image of it on the other side of the aperture. The most obvious bearing of this in artist's work is that if the sun shines through the narrow apertures left by leaves in a thick wood, we shall have images of the sun on the ground; the shadows of the leaves will be dominated by circular intervals, and the higher the leaves the larger these circles will be. During the eclipse of 1870 the images of the delicate crescent of the sun thrown on the ground through the orange and olive trees were most perfect in form, and produced a strange effect never to be forgotten.

The laws of reflection can also be studied without any higher knowledge of the properties of light, and the difference between "specular reflection," the case in which light is reflected as in a mirror, and "scattering," in which, in consequence of the roughness of the surface on which it falls it is thrown off in all directions, will be at once recognised.

Water is the great reflector employed by the artist. Take, for instance, No. 643 in this year's Academy. If a painter will imagine a vertical plane passing through the object reflected—say a hill-top, and his eye; and plot a section with the height of his eye and the hill-top above the water and the distance between them roughly to scale; and if he will further recollect that the lines which connect the reflecting point of the water with his eye and the hill-top must make equal angles with the water level, he will find all he needs to insure correctness. In a picture taken, *e.g.*, with the eye at *a*, in the annexed woodcut, he will not include the distant hill-top at *y*, while with the eye at *b* he would do so.

In tranquil water the same consideration determines the locus of the reflection of the sun or moon. But if there be scattering, there will be a wake. The above reasoning will show that it will be absolutely incorrect to throw this wake athwart the picture; nevertheless, this has been done, and by artists of the highest celebrity.

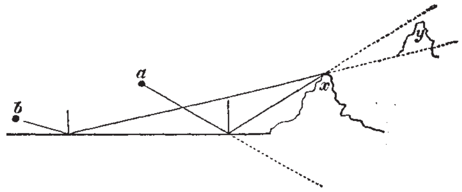

FIG. 1.

It is, perhaps, in the case of reflection of light by the poor moon that the modern artist comes to the greatest grief; and yet the only peculiarity in this case of reflection of light is that we are dealing with reflection from a spherical body which changes its place with reference to the light source and our eyes. If an artist would amuse himself any evening with his children in imitating these conditions with a lamp and some oranges he would never make another mistake. We should have moons painted with discretion instead of *à discretion*, and I fancy the "balance of the picture" would be found to be much less frequently disturbed by scientific accuracy than is generally imagined. I have known an artist to defend a crescent moon directly opposite a setting sun on the ground that if the moon had been painted full this much-prized "balance of the picture" would be entirely upset; and yet when it was suggested that the effect of two moons should be tried the idea was scouted as ridiculous—why, I could not understand from the standpoint taken by the artist.

Five minutes' reading of any elementary astronomy is all that is necessary to show that when the moon is on one side of the horizon, say east, and the sun on the other, say west, the observer must be between them, and that therefore the moon's reflecting side in its entirety must be turned towards him. It will not want even this amount of reading to convince him that if a sunset is painted as in Fig. 2, by no possibility can a globe at *a* be lighted up, as shown. Nor can it be lighted up by the sun as shown at *b*, because the sun must be somewhere on the dotted line. If the moon is drawn at *c* the illumination must be symmetrical with reference to the line joining the moon and sun, and the nearer the moon is apparently to the sun, the more delicate must the crescent be.

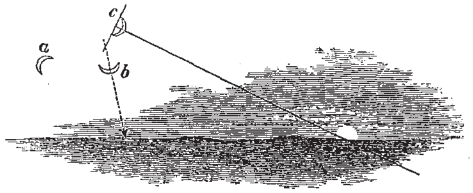

FIG 2.

Enough for the present on this subject. There is, however, one other point worth notice, which, although it is more astronomical than physical, I may perhaps be allowed to refer to here. When an artist wishes to introduce a constellation as well as a moon into his picture, he should especially avoid the familiar northern ones, especially the Great Bear, as the moon has never been known to pass through that constellation. Still if my memory serves me, she has been painted in her silent majesty rendering glorious the sky over a village church, represented broadside on with the chancel to the right. She had therefore been caught due north in an unguarded moment. With an *English* village church (which is bound to be truly oriented) represented in the fashion I have indicated it is also as well to avoid the temptation to show up the stained glass windows of the aisles by introducing a sunset behind them.

I wish to be as little digressive as possible, but there is one point more which demands a word in passing. If an artist will put the moon or the sun into a picture, he should understand that in nine cases out of ten he lays down an almost perfect scale by which the accuracy of his delineation of landscape may be tested. In spite of the strange physiological effect which gives us the exaggerated sensation of the size of the sun or moon when they are near the horizon (so that we can compare them with familiar objects), the real variation is practically *nil*, and for our purpose it is enough to say that both sun and moon steadily subtend an angle of half a degree. Now it is because we can observe this angle and because we know the distance of the sun and moon as well, that we can calculate the sizes of these luminaries. Similarly, if an artist paints Peckham Rise from Camberwell or Mount Everest from the valley of Cashmere (supposing either picture possible—I don't know), and then puts a sun or moon in, *par dessus le marché*, he gives all the data necessary for the determination of the height and size of the hills in question.

By the kindness of an American astronomer I can give some statistics of considerable interest on the heights of hills in the United States as roughly surveyed in this way—that is as determined by pictures in which, by means of the moon or otherwise, the necessary data are provided. The pictures on which they are based were exhibited in 1876 and 1877. One mountain (I think it was in Missouri, but its exact name has escaped me) reached the respectable elevation of 105 miles. The average height in the United States generally, taking the pictures all round, was 43⅔ miles. There was only one artist who had got a hill into his picture less than thirteen miles high, but he only succeeded in doing this once.

So much then with regard to reflection, and the digressions which reflection has suggested.

So far there has been nothing said about colour.

It has been known from the time of Kepler that the white light of the sun, and indeed of all bodies which emit it, is not the simple thing we have so far taken it to be. It is really a sensation produced in our eye by the commingling of an innumerable series of different wave-lengths of light, each one of which, taken separately, we are bound to consider as a pure colour from the physical point of view, however we regard the physiological action which gives rise to the sensation.

Nature shows us in the rainbow, about which I shall have something to say by and by, the breaking up of this complex beam of white light into its various elements. The physicist arrives at the same result by employing a prism. A round hole in a shutter, through which a beam of light is allowed to enter into a dark room, and a common lustre inserted in the path of the beam, is all that is required in the way of apparatus to demonstrate the marvellous phenomenon of the analysis of white light into its constituent elements.

We not only get colour as the result of the analysis of white light, but we get it as a result of molecular structure, that is, some bodies like the sun and a candle give us that kind of light which we can break up into a complete series of coloured constituents; other bodies give us light which is not white, which is coloured to begin with, and so remains coloured to the end of the chapter.

Let us now pass on to those principles, the application of which to the coloured phenomena with which artists have to deal will, I am sure, prove of the greatest interest. Here we must grope our way as well as we may be able in a region where at present the senses are entirely powerless. We are in the world of the infinitely little. We approach one of those questions of molecular physics which no doubt in a few years must become one of the chief fields of investigation to men of science.

If I take a lump of iron, it is in what is generally called the solid state. If I apply heat to it it becomes molten, and we call it liquid. If the heat is still further increased, we drive the molten iron into iron vapour, as we more commonly drive water into steam.

Now we have achieved these results gradually, breaking down the molecular structure of the iron and of the water until at length we have got the molecular structure down to that of its ultimate fineness; so that when we have got to the stage of vapour at the end of our labour we have got a condition of things in which the smallest particles, or the ultimate molecules, which go to make up iron and water are there in their individuality and exist as separate points.

Now, what can this have to do with colour?

It has this to do with it: if I make a lump of iron hot, it gives out light, because its molecular constitution is disturbed or rendered more disturbed by the conditions to which we expose it when we heat it, and this state of unrest is rendered visible to us by the phenomena of light. Here we have simply the reason why there is a visible universe at all. If it were not for the condition of unrest of matter, we should never see anything; and, therefore, so far as the sensation of light is concerned, the visible universe would cease to exist altogether if this condition of unrest were abolished.

This being so then, let us take each of those molecular groupings in the solid iron as being in a state of unrest. Let us take for granted that the phenomena of sight depend first upon the state of unrest; secondly, upon the state of unrest being communicated to the surrounding ether, which, as we have already seen, does for light what air does for sound; and that the state of unrest of the molecules of iron having set up an equivalent state of unrest in the ether, or, if you like it better, having set up a chain of vibrations in the ether, this ether is competent to communicate its own vibrations thus imposed upon it to the optic nerve in our eye.

It brings before that nerve such an accurate reproduction, so to speak, of the vibrations which were communicated to it at the other end by the vibrations of the molecules of iron, that we have the impression that we see a mass of white hot iron, because the ether was agitated by precisely a mass of white hot iron in the first instance.

Now, if we observe any mass such as this, giving us light in the ordinary way, we get merely the impression of form; but if we admit such white light to our eye through the prism, we get it transformed into a band of colour called a spectrum, because, as we have already seen, white light is built up of a gamut of light notes from the lowest note to the highest; that is—to talk in the language of colour—from the extreme red to the extreme violet, through all those colours which are so gloriously brought before us in the rainbow, and more too.

But this does not happen with all substances.

Let us go now from our mass of white hot iron back to those smallest particles of iron vapour, those ultimate molecules to which I first drew attention. If we subject the light which comes from them to the same treatment, that is, if we allow it to come to our eye through a prism, we find that we don't get the whole gamut of colour represented as in the former case. We only get a light note, so to speak, here and there. Ordinarily, the phenomenon is presented to us in consequence of the construction of the spectroscope, by a series of lines, because ordinarily the spectroscope, is so arranged that the vibrations from any set of molecules are made to paint for us images of a fine aperture called a slit, through which the light is made to pass. If the light is discontinuous so far as the gamut of light is concerned, we only get a light note here and there. If it is continuous, the series of images is continuous; and we get what is termed a continuous spectrum, that is, the band of rainbow tints.

Now, mark this well, that when we treat the vapours of all metals that we know of in this way, we find that the arrangement of these bright lines, the arrangement of the images of the slit in other words, is different in the case of the vapour of every metal, so that we may say that no two vapours in Nature have the same colour.

We are now justified in saying, speaking in the language of molecules, that when we drive any chemical substance down to its ultimate fineness, and cause the ultimate molecules of each such chemical substance to vibrate, the vibrations from each chemical substance communicated to the ether and by the ether to our eye are so distinct that if we will take the trouble to record the effects thus obtained, we are for ever afterwards able to recognise the vibrations of that particular molecule, in whatever conditions we see those vibrations thus rendered spectroscopically visible to us, whether the molecules we are examining are in our laboratory, or in the most distant body in the depths of space.

The blue part of the spectrum which we obtain when we examine the light which is communicated to our eye by the vibrations of the finest particles of manganese, to take an example, contains a series of lines absolutely without any arrangement—a broad band here, a single line there, a double line elsewhere, and so on. In iron the arrangement of the lines is perfectly different. They are more numerous, and a detailed examination would convince us that it is quite as easy to make as definite a map of such a spectrum, and thus to point out the differences, as it is easy to make a map or drawing of any two things which differ in themselves.

This is sure and certain knowledge. It seems to deal with a condition of things with which the artist will never have to do. This is so, but the necessity for the statement of these facts will be abundantly seen in the sequel in which I hope to show that between the two extreme molecular stages to which I have drawn attention, that which always gives us white light, and that which gives us coloured light, the colour *in no case* being the same, we have stages with coloured light which practically is *always the same* for all bodies. J. NORMAN LOCKYER

THE AMERICAN STORM WARNINGS[1]

STORM movements from west to east over Europe are familiar to your readers, yet I will refer briefly to them here. The chief storm routes are as follows:—From the regions immediately north of the British Islands to the Norwegian coast and over the Scandinavian Mountains to the Eastern Baltic and Central Russia, thence crossing the Ural Mountains into Siberia. From the British Islands directly to Denmark, North Germany, and Southern Russia to the regions north of the Caspian Sea, and from the British Channel, over the Netherlands, to Central Europe, passing north of the Alps into the Danube valley, and over the Black Sea to Asia Minor. The influence of position of the area of high pressure southward of the storm track on the direction of the latter is very great. Whenever the first described route is followed, the pressure is high over Great Britain, France, and Central Europe, and is falling in the Mediterranean and Northern Africa. If the second route is taken by the storm the barometer is high over Spain and the Mediterranean, giving the zone of low pressure a generally eastern direction. When the last-described route is followed, the pressure is high in the Atlantic off the coast of France and Spain, leaving a relatively low pressure over Great Britain, Southern Norway, and Sweden, the Western Baltic, and Central Europe.

The heaviest rains occur along the west coast of France and the British Islands, and on the Norway coast. The precipitation lightens eastward and south-eastward to Central Europe, but seems to increase again in the Danube valley, where the influence of moist air from the Mediterranean basin operates in increasing the energy of the storm. Over the whole field minor disturbances are frequently developed by the movements of the high pressures, which rarely become serious storms.

We must regard a knowledge of the general movement of the atmosphere as essential to success in the prediction of the movements of storms, their arrival in different regions, and their character. During the past year I have followed out and depended on the operation of what I conceive to be a law of atmospheric movement which I deduced from observations of the changes that occur over the areas of the American and European continents

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[1] Continued from p. 34.